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# JET ENGINES FOR AIR-HEATER SERVICE AT NASA-LEWIS RESEARCH CENTER


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The concept of using jet engines for a heat source was developed to provide an expedient and economical means for heating large quantities of high-pressure air. Such air is needed for facilities where full-scale components of current and future air-breathing engines will be investigated for performance.

The requirement for the first facility was set at 285 pounds of air per second at 100 psig and 1200° F at the test site.

A search for commercially available equipment indicated a sparcity of tried and proven equipment that would fulfill the need. At best a multiple unit arrangement was proposed by the industry; but, upon examination the multiple unit was found to be too cumbersome for the available space and prohibitive in cost.

The alternate choice appeared to be the rehabilitation of an existing heat exchanger which was located in the close proximity of the new facility, to heat the air to 600° F. Then, this heat exchanger could be topped with two in-house design shell-tube heaters in parallel, each fired with an Air Force surplus J-57 jet engine equipped with an in-house design afterburner, (fig. 1).

The topping heater (fig. 2) consists of a bundle of 639 stainless-steel tubes which have an outside diameter, 1.5-inch, 0.083-inch wall, and are 31.5 feet long. The tubes are spaced at a 1.875-inch pitch triangular pattern, rolled, and welded at each end in a tube sheet. The outer shell is made of 3/4-inch stainless steel. An expansion joint is provided to accommodate the relative expansion between the tube bundle and the shell due to temperature differences. The tubes are intermittently supported by baffles which are tie bolted to a tube sheet, and provide freedom to the tubes to move through their sockets. Heating gas and heated air are made counterflow: gas through the tubes, and air across and parallel through the spaces surrounding the tubes.

In design calculations, tube sizes, lengths, and spacings were optimized for utilizing the maximum available pressure drops in striving for maximum overall heat-transfer coefficients. In as much as the air flow pattern is an indeterminant combination of parallel and cross flow, the more conservative coefficient values for parallel flow were used. The actual test results showed a 20-percent-higher overall heat-transfer coefficient than the assumed values at the design point.

The afterburner consists of two concentric annular V-shape "gutters" interconnected with six radial "gutters" forming a wheel. The gutters are made of perforated type-316 stainless-steel sheets welded to a pipe at their apex. The pipes in each gutter serve as fuel manifolds. Natural gas from the 50-psig distribution system is injected through orifices drilled in the pipe manifolds. Initially an igniting burner was located at the center of the wheel to ignite the gutters radially outward. The hot environment in the center of the afterburner and the relative inaccessibility made the maintenance of the igniter burner burdensome. An alternate arrangement of two igniters located 180 degrees apart in the outer periphery, just ahead of the outer gutter, proved more satisfactory from a maintenance standpoint.

The afterburner was designed with a capability to raise the engine exhaust gas temperatures by up to $600^\circ$ F. Because of materials limitations, an average temperature ceiling of $1500^\circ$ F was imposed with permissible spot variations of $\pm 100^\circ$ F at the face of the inlet tube sheet. During the earlier runs the variations exceeded the allowed $\pm 100^\circ$ F. The condition of the center of the tube sheet running consistently cooler was attributed to the shadow cast by the ignitor. Upon relocation of the ignitor, a few more fuel orifices were drilled in the spokes near the center of the wheel; this materially helped to even out the temperature distribution.

The conversion of the engines to use natural gas necessitated using a compressor to boost the gas pressure from the distribution line pressure of a nominal 50 psig to a 250+ psig level required by the engines. A two-stage reciprocating piston-type compressor was procured which had a rated capacity of 300 000 standard cubic feet per hour to 300-psig pressure level. An existing 1500-horsepower motor was utilized to drive the compressor through a 3/1 gear reduction unit.

Because of the remote location of the compressor, dictated by space and operational man-power considerations, nearly 1000 feet of supply piping was "piggy backed" on existing overhead pipe lines to reach from the compressor to the test cell. During the severely cold weather some difficulties were experienced with filters clogging by ice formed from the condensate in the exposed pipe line. This difficulty was overcome by reducing the aftercooling at the compressor outlet, thereby raising the gas temperature in the pipe, and by installing centrifugal separators to eliminate condensation and ice before reaching the filters. As an added measure, the line will be insulated before another winter.

The conversion of the engines and the afterburners to use natural gas was prompted by three considerations. First and most important was to combat poluttion. In as much as the test cell is located in an area adjacent to one of the glide paths leading to neighboring Cleveland Hopkins Airport, the use of tall stacks are prohibited. Exhaust from jet fuels discharged at a low level could be objectionable to the laboratory personnel as well as to the nearby communities.

A second consideration was the economics. Natural gas in the Cleveland area, at the time of the design, cost industrial users 0.53 cents per 1000 cubic feet, or 57 cents per million usable Btu. Jet fuel, on the other hand cost 0.11 cents per gallon, or $1.02 per usable million Btu. During operation at the design rating, the cost saving in fuel amounts to $186.00 per hour.

A final consideration was the savings in logistics. The existing limited fuel storage facilities would necessitate frequent deliveries of jet fuel which would involve a great deal of manpower use.

Therefore, three considerations;~~of~~ cleanliness, economy, and convenience undisputably favored the use of natural gas in preference to jet fuel.

Based on the successful operation of these heat exchangers in the first test facility, a second and a larger facility, which is now under construction, will also be equipped with three more of the same size and type heat exchangers. Provisions have been made to add a fourth unit at some future date.

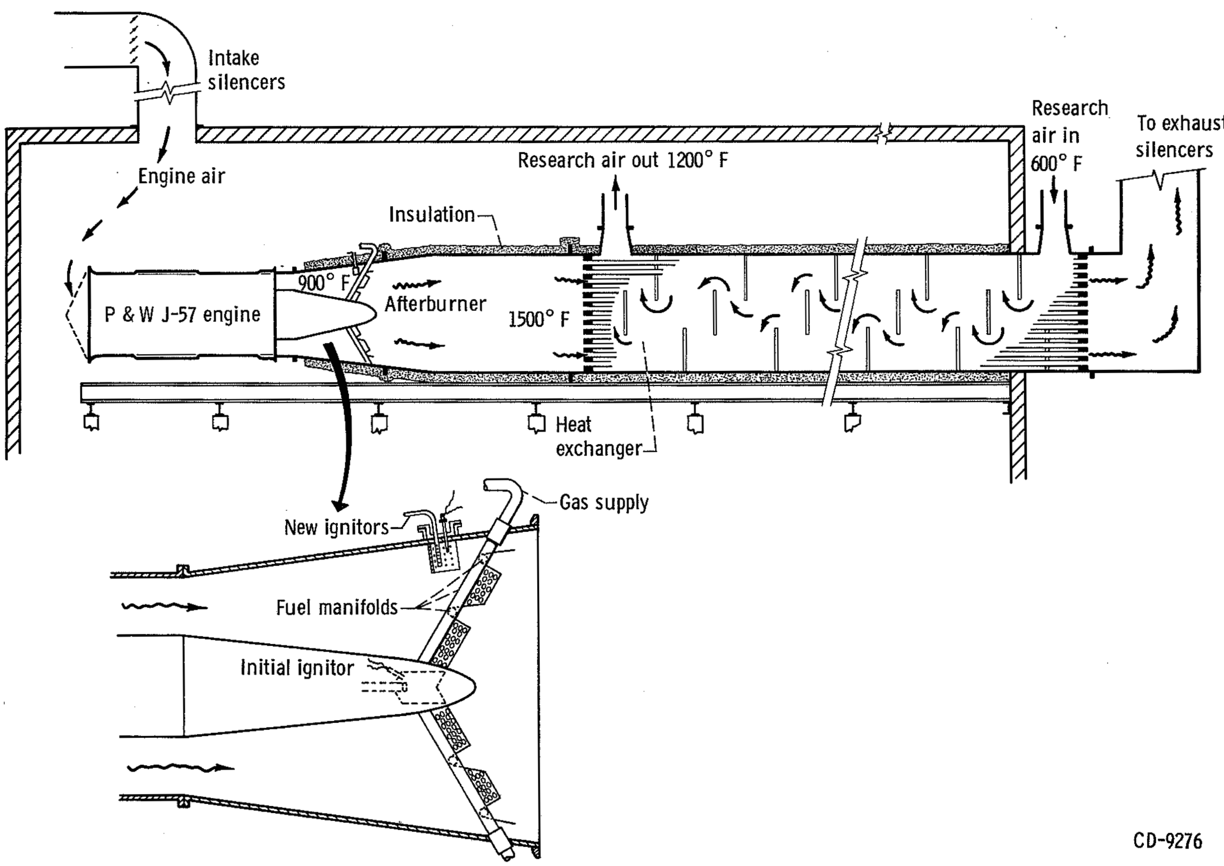


Figure 1. - Vertical profile of engine afterburner and heat exchanger in test cell.

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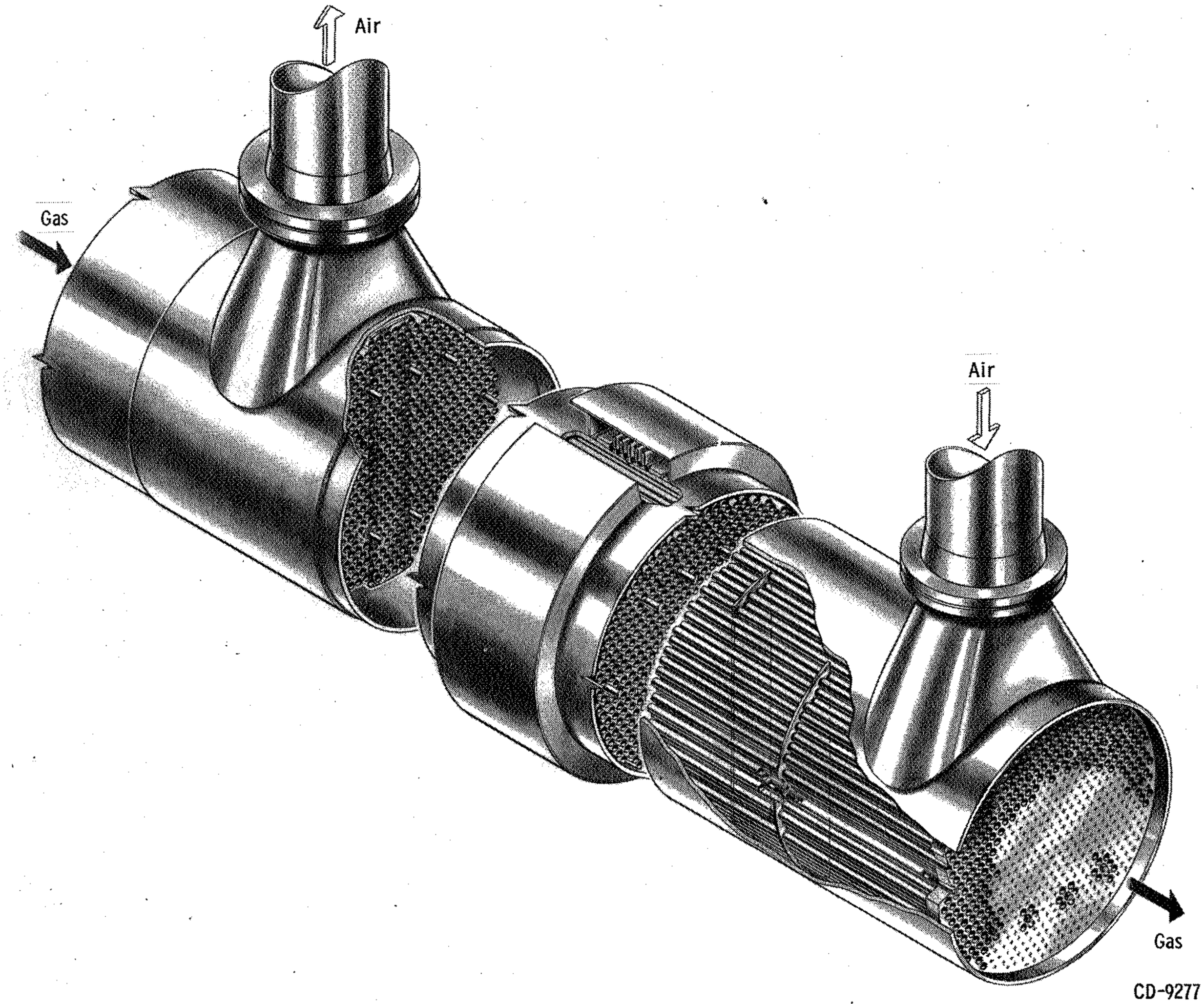


Figure 2. - Heat exchanger.